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LARGE TELESCOPE EXPERIMENT PROGRAM (LTEP)

FINAL TECHNICAL REPORT

Volume I. Summary Report

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Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

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LARGE TELESCOPE EXPERIMENT PROGRAM (LTEP)

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Huntsville, Alabama

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Lockheed Missiles & Space Company

A Group Division of Lockheed Aircraft Corporation

Sunnyvale, California

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FOREWORD

The Lockheed Missiles & Space Company (LMSC), Sunnyvale, California, in support of the Perkin-Elmer Corporation, Norwalk, Connecticut, performed the three-part Optical Technology Experiment System (OTES) Phase A study in the period 1965 to 1967. These studies considered various possible approaches to implementing alternate space telescope configurations. A primary result of these conceptual design considerations was the generation of a spacecraft/2-meter telescope configuration which indicated the feasibility of implementing this system.

In July of 1969, LMSC initiated effort on a follow-on study of the 2-meter system in support of Perkin-Elmer efforts on the Large Telescope Experiment Program (LTEP). These analyses and considerations of the spacecraft and related areas of program support were based, primarily, on the basic configuration described in LMSC Report No. A848294, "Optical Technology Experiment System (OTES), Phase II – Final Technical Report", dated 15 September 1967. Subsequent developments have included NASA selection of the AAP Saturn dry workshop (SWS) cluster configuration, evolution of the space shuttle/space station, and adaption of the optical experiments for space astronomy technology development and astronomy operation. The LTEP study has reviewed and updated the results of the previous OTES effort, integrated consideration of the subsequent developments and defined the areas for technical concentration in an early Phase B follow-on study program.

The results of the LTEP spacecraft support study are summarized in this Final Report input. The feasibility of the 2-meter concept has been validated, the configuration modified consistent with the current AAP system, alternate operating modes defined and a firm basis established for a Phase B Large Stellar Telescope (LST) study program. The report is contained in two volumes; Volume I – Summary Report and Volume II – Technical Report.

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CONTENTS

ILLUSTRATIONS

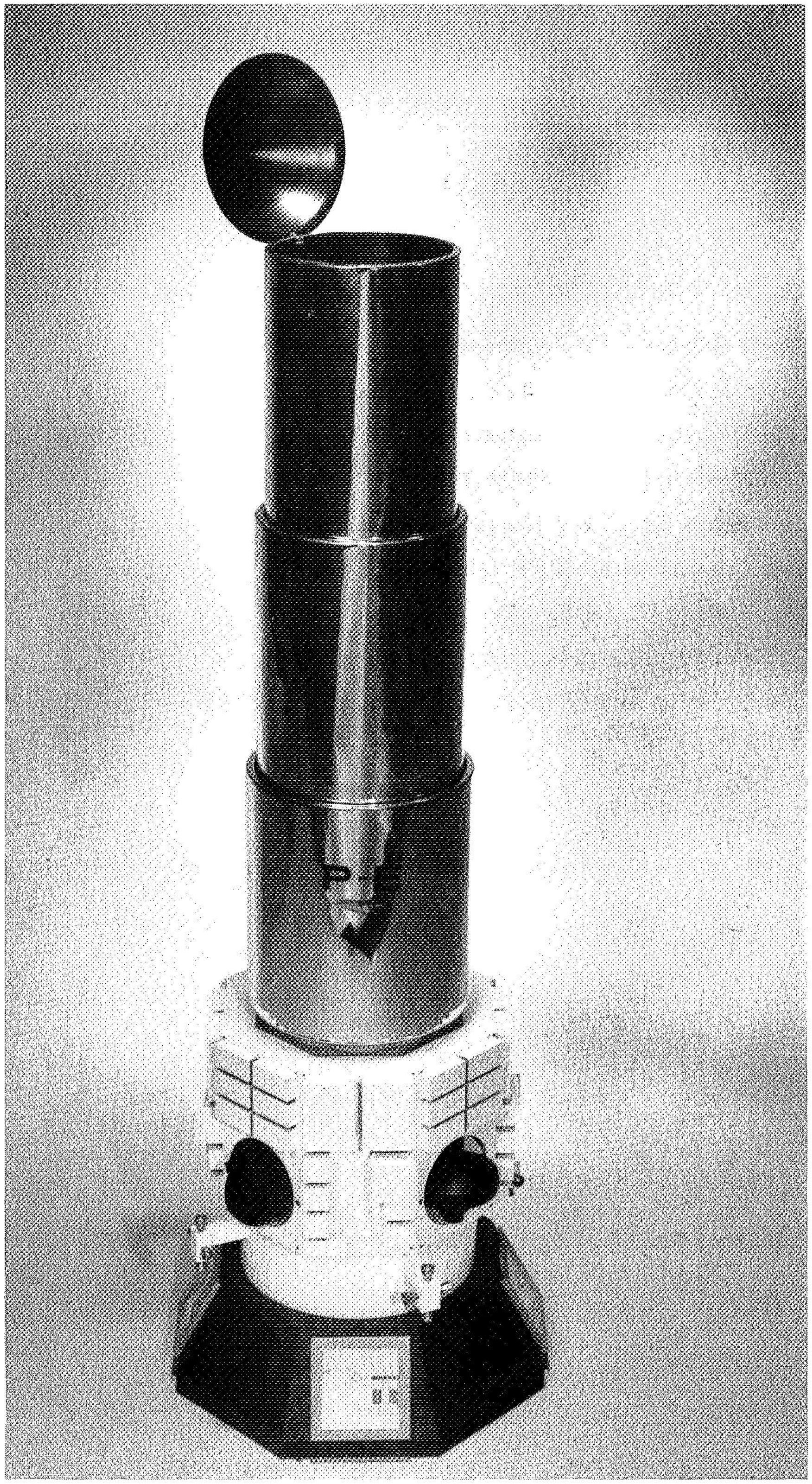


Fig. 1 The 2-Meter LTEP Concept

1.1 INTRODUCTION AND SUMMARY

The Lockheed Missiles & Space Company (LMSC), Sunnyvale, California, in support of the Perkin-Elmer Corporation, Norwalk, Connecticut, performed a follow-on study of the 2-meter system for the Large Telescope Experiment Program (LTEP). The program consisted of analyses and considerations of the spacecraft and related areas of program support. The LTEP study has reviewed and updated the results of previous efforts, integrated consideration of subsequent developments and defined the areas for technical concentration in an early Phase B follow-on study program. The feasibility of the 2-meter concept (Fig. 1) has been validated, the configuration modified consistent with the current AAP system, alternate operating modes defined and a firm basis established for a Phase B study program.

Figure 2 is an illustration of the baseline LTEP Module which resulted from the LTEP study effort. The four basic elements and sub-elements thereof are:

- Telescope Assembly. This assembly consists of a three-section tube, an electro-optical equipment compartment, a C. G. positioner, and experiments.
- ATM Rack (Modified). The Telescope Assembly mounts into the gimbal rings of the ATM Rack. The inertial platform components, three large Control Moment Gyros (CMG's) and associated electronics, the batteries and controls of the electrical power subsystem, and the gimbal fine-pointing control system are mounted on the Rack structure.
- Solar Arrays. Two of the four ATM solar array wings are mounted on the ATM Rack (not shown in Fig. 2). They are rotatable about a single-hinge axis.
- Propulsion/Support Module (PSM). A cylindrical module attaches rigidly to the end bulkhead of the ATM Rack. This sheetmetal structure contains the remaining supporting subsystems for the LTEP system which includes axial and attitude control thrusters, attitude control subsystem, propulsion subsystem, the auxiliary electrical power subsystem and the communications and instrumentation subsystem.

1.2 MISSION CONSIDERATIONS

The sequence of events will be the same for the AAP Cluster/LTEP combination as contemplated for the AAP-1 mission with the ATM Solar Telescope. The Cluster configuration (Workshop, Airlock Module, MDA, CSM) will be identical for the Cluster/LTEP mission. Utilizing the Saturn V booster elements, launch azimuths for the LTEP mission are limited to the normal range-safety constraints (generally 45 deg up to 110 deg). However, to achieve orbital inclinations of interest for the LTEP system at 35 deg, launch azimuths well within these limits may be used. A launch window of one hour is available by accepting a tolerance of ±7.5 deg on the initial right ascension of the ascending node, assuming a fixed launch azimuth and no yaw steering. Such a tolerance seems reasonable because the orbit will have a nodal regression rate of 6.57 deg per day inertially, or 7.56 deg per day with respect to the sun. A cycle with respect to the sun is then completed in 47.6 days.

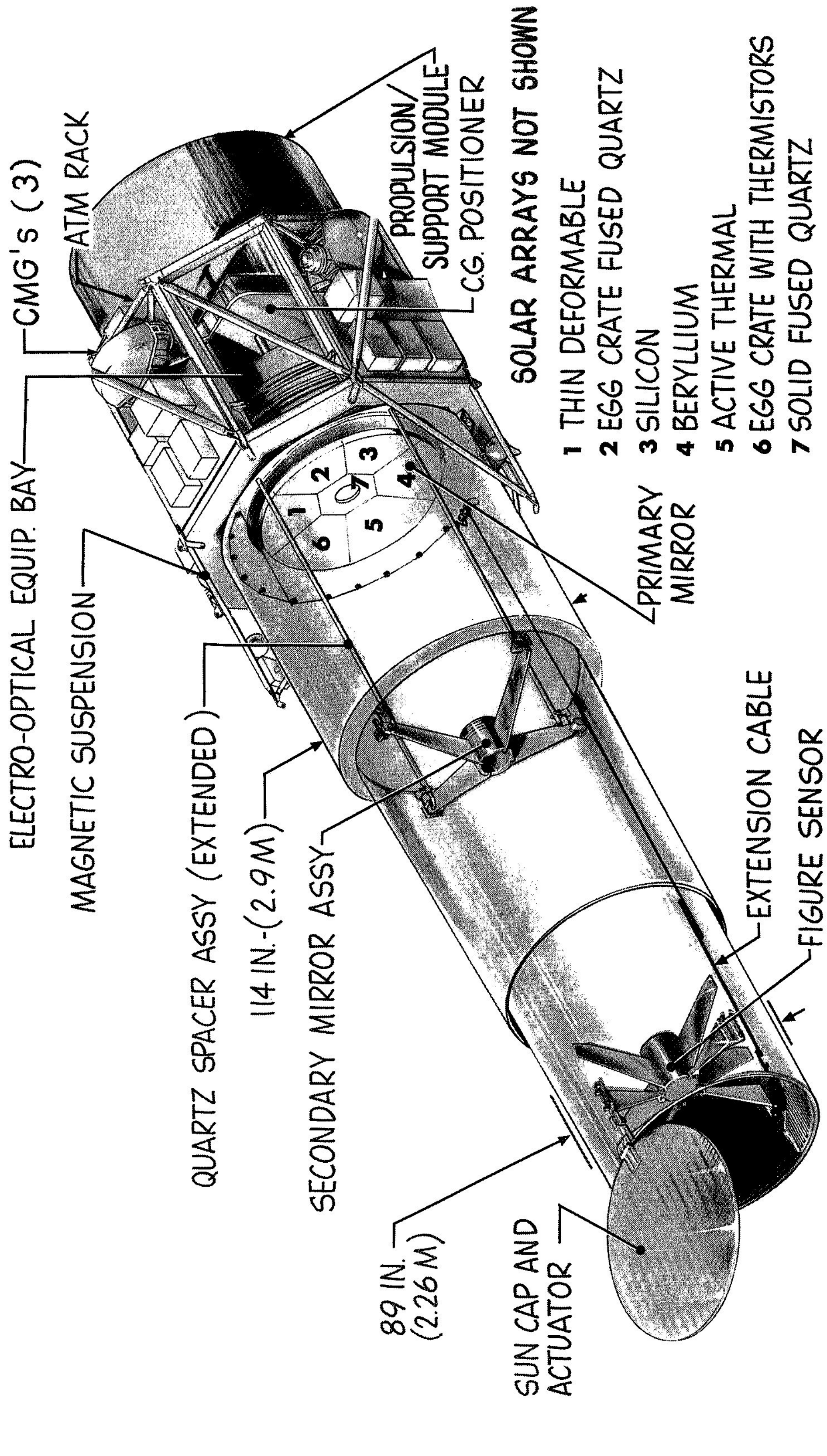


Fig. 2 Overall Configuration of LTEP Module

In the piggy-back launch of the LTEP system on the AAP Cluster (SWS-II), the selected launch profile places the Cluster/LTEP into a circular orbit 220 nm altitude, with 35 deg inclination, launched from the Eastern Test Range (ETR). The Saturn V launch vehicle derivative (SIC stage plus SII stage) with the Cluster/LTEP would be the first of several launches. No known launch window nor launch period requirements are imposed on the launch. A possible source for a launch window constraint is the specification of the initial longitude of the ascending node to satisfy special scientific objectives, such as observing astronomy targets within the first few days of operation. Such a nodal specification is likely to have sufficient tolerances so that no launch window problems will occur.

The principal features of the recommended LTEP configuration are as follows:

- Accommodation of a full 2-meter diameter primary mirror of either a segmented or monolithic design
- Employment of a movable secondary mirror and figure sensor
- Accommodation of the experiment for comparison of mechanical and magnetic suspension systems
- Provision for controllable positioning of the telescope center of gravity
- Provision for rigid one-piece quartz spacer rods to assist in maintaining focus
- Maintenance of low thermal gradients across the diameter of the primary mirror with long life pressure elements
- Provision for launch "piggy-back" on the AAP Dry Workshop Cluster; the same experiment also may be launched on either a Titan IIIC or Saturn IB in alternate modes
- Provision for fully automated erection of the telescope
- Operational flexibility for both Cluster-attached and Independent modes
- Provision for development economy through maximum use of previously developed and qualified Apollo program hardware
- Astronaut participation in maintenance and operational tasks.

As a principal guideline, the proposed system will use a 2-meter diameter, seven-segment, active-optics primary mirror telescope system and will mate with the Apollo Telescope Mount (ATM) Rack. The primary mode of operation is in the AAP Saturn Dry Workshop (SWS-II) cluster although operating modes with the early space station and independent of any earth-orbiting manned cluster system were considered. Only stellar target orientation was assigned to the telescope system. The resulting concept and recommended program will establish firm data that can serve for either a technology development system or an early operational space astronomy instrument.

The following guidelines were used for the LTEP spacecraft support study:

- A 1974-75 time frame was assumed for the SWS-II or independent launches; the space shuttle and/or space station piggyback approaches were based upon initial launch operations in the 1976-77 time frame.
- A minimum of 2-years operation of the system is required. A 10-year on-orbit capability is desired when periodic resupply and maintenance is provided.
- The program will be implemented with a maximum economy and probability of success by using "off-the-shelf" hardware and techniques to eliminate development of experiment support hardware to as great a degree as feasible.
- Reliability will be in full compliance with AAP objectives for a system (mission) goal of 0.90 and a crew survival goal of 0.999.
- The AAP SWS-I mission plans for crew rotation periods will apply to the LTEP mission. Crew tasks include direct or remote experiment operations, equipment maintenance and operations, mirror segment removal, and film replacement and retrieval.
- The thermal gradients (radial) across the primary mirror will not be in excess of $1^{\circ}C$. The operating temperature will be on the order of $-80^{\circ}C$. The attitude control and pointing system shall provide a ±2.5 arc sec accuracy.
- The nominal AAP orbit (220 nm circular, 35 deg inclined) is assumed for the system. (Possible space station orbits of 250 to 350 nm and 50 to 55 deg inclinations should not significantly affect feasibility implications of the system concept.)

The study goal has been to consider two alternate means of implementing the 2-meter configuration; as a piggyback on an existing NASA manned program or as an autonomous, independent program effort. As a result of study efforts, the baseline mode of operation involves the Apollo Applications Program (AAP) with the Saturn launch vehicle family. (The early space station, leading to the spacebase, and using the space shuttle vehicle was also considered as a piggyback-program potential.) Both hard-docked, i.e., an integral portion of the AAP cluster configuration, and subsequent detached (remote, or free-flying) operation is involved in the baseline mode. Three principal alternatives to this baseline approach were considered. The baseline and alternate system configurations are indicated in Fig. 3.

For the independent or autonomous approach, a Titan IIIC launch vehicle and appropriate unmanned LTEP configuration was selected. This launch vehicle could also be used to separately launch the LTEP for subsequent rendezvous with the AAP cluster as a secondary AAP experiment mode of operation. An independent manned/astronaut-supported operation was considered using the Saturn IB launch vehicle. This system involves use of the LMSC-conceived Manned Orbital Telescope Experiment Laboratory (MOTEL).

1.3 SPACECRAFT SYSTEMS

1.3.1 The SWS-II LTEP (The Baseline Program Mode)

The operational modes considered for evaluation of the LTEP concept are shown in Fig. 3. The baseline mode of operation is the AAP Saturn Workshop (SWS-II) approach. The previously proposed OTES 2-meter telescope design was constrained by the available payload volume of the Saturn IB launch vehicle and payload fairing. The decision by NASA in mid-1969 to change over to the Dry Workshop concept for the AAP Cluster provided considerably more payload volume and allowed reconcepting of the telescope stowed configuration. With the change to the Dry Workshop principle, the LM Ascent Stage was eliminated from the AAP Cluster operations. The ATM Rack and the Solar Telescope are mounted atop a new support truss and swing links forward of the SIVB, the Airlock Module (AM), and Modified Docking Adapter (MDA). A new, large-volume payload enclosure is provided to house the payload elements during launch and ascent.

Because of the elimination of the LM Ascent Stage and Orbital Mirror Recoating Facility, OMRF, (removed after analysis indicated recoating of mirrors could not be accomplished at the low Earth-orbiting altitude because of oxidation of coating by residual oxygen in the 220 nm environment), the telescope assembly can be mounted above the ATM Rack. The primary axial-aft launch loads will not tend to extend the telescope; the external caging/restraint frame provided on the OTES concept can therefore be simplified and/or lightened considerably. The larger longitudinal space also allowed reduction in the quantity of telescoping sections. The critical-clearance condition for fit within the applicable payload fairings occurs at the forward maximum diameters of the stowed envelopes. The primary operational mode for application of the LTEP system consists of launching the LTEP Module rigidly attached to the AAP Workshop Cluster and utilizing the Cluster as an orbiting platform (Fig. 4). Alternate operation within this basic mode will include release of the LTEP Module from the Cluster and free-flight of the Module in station-keeping relationship to the Cluster.

Saturn V derivatives, stages SIC and SII, will be used to boost the Dry Workshop Cluster to the 220 nm orbit. The LTEP Module comprises a Propulsion/Support Module, a modified ATM Rack, solar arrays (folded for launch), and the LTEP Telescope Assembly. After separation from the SII stage at the "separation line" shown and jettison of the 762-inch long fairing, the Cluster is ready for initial operations (preceding crew arrival in a separately launched Apollo CSM).

On the Saturn V launch, the ATM Rack will be attached rigidly to the two swing links. All g loads will be carried through the telescope structure to the mounting interface on the ATM Rack inner gimbal ring. The inner gimbal ring will transfer the loads via the outer gimbal ring and roll ring to the ATM Rack structure. The primary launch loads will be axial-aft, approximately 6 g maximum. The current ATM Rack flexural pivots, providing the gimbal ring supports and hinge points, are designed to support the weight of the ATM spar and experiment, approximately 5535 lb; the weight of the LTEP telescope (gimballed mass) is about 8100 lb. The flexural pivot capability, both in launch loading and reaction in zero-g with the higher moments of inertia should be examined carefully in a follow-on study.

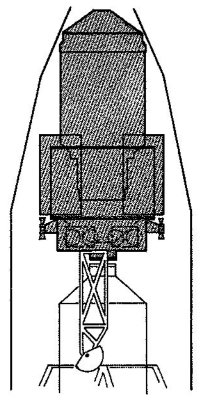
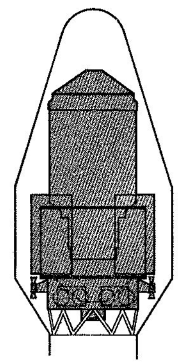
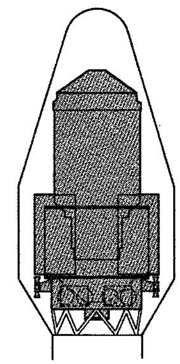
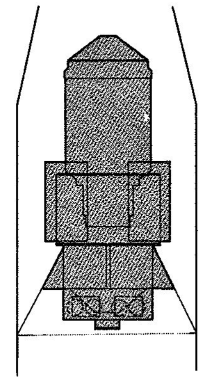
MODE →	THE SWS-II LTEP ① AAP SATURN WORKSHOP	THE TITAN IIIC LTEP ② INDEPENDENT UNMANNED	THE RENDEZVOUS LTEP ③ INDEPENDENT LAUNCH CLUSTER OPERATION	THE SATURN IB LTEP ④ INDEPENDENT LAUNCH MANNED CAPABILITY
LAUNCH ENVELOPE				
LAUNCH VEHICLE	SATURN V	TITAN IIIC	TITAN III C	SATURN IB
SYSTEM EQUIPMENT	2 METER TELESCOPE ATM RACK PROPULSION/SUPPORT MODULE	SAME AS MODE 1	SAME AS MODE 1	SAME AS MODE 1 PLUS MOTEL
MANNED SUPPORT	AAP SATURN IB LAUNCH	NONE	AAP SATURN IB LAUNCH	SATURN IB LAUNCH
KEY FEATURE	INTEGRAL CLUSTER EXPERIMENT	UNMANNED SIMPLIFIED EXPERIMENT	AAP EXPERIMENT AUTONOMOUS LAUNCH	AUTONOMOUS-MANNED SUPPORT CAPABILITY

Fig. 3 LTEP System Configurations

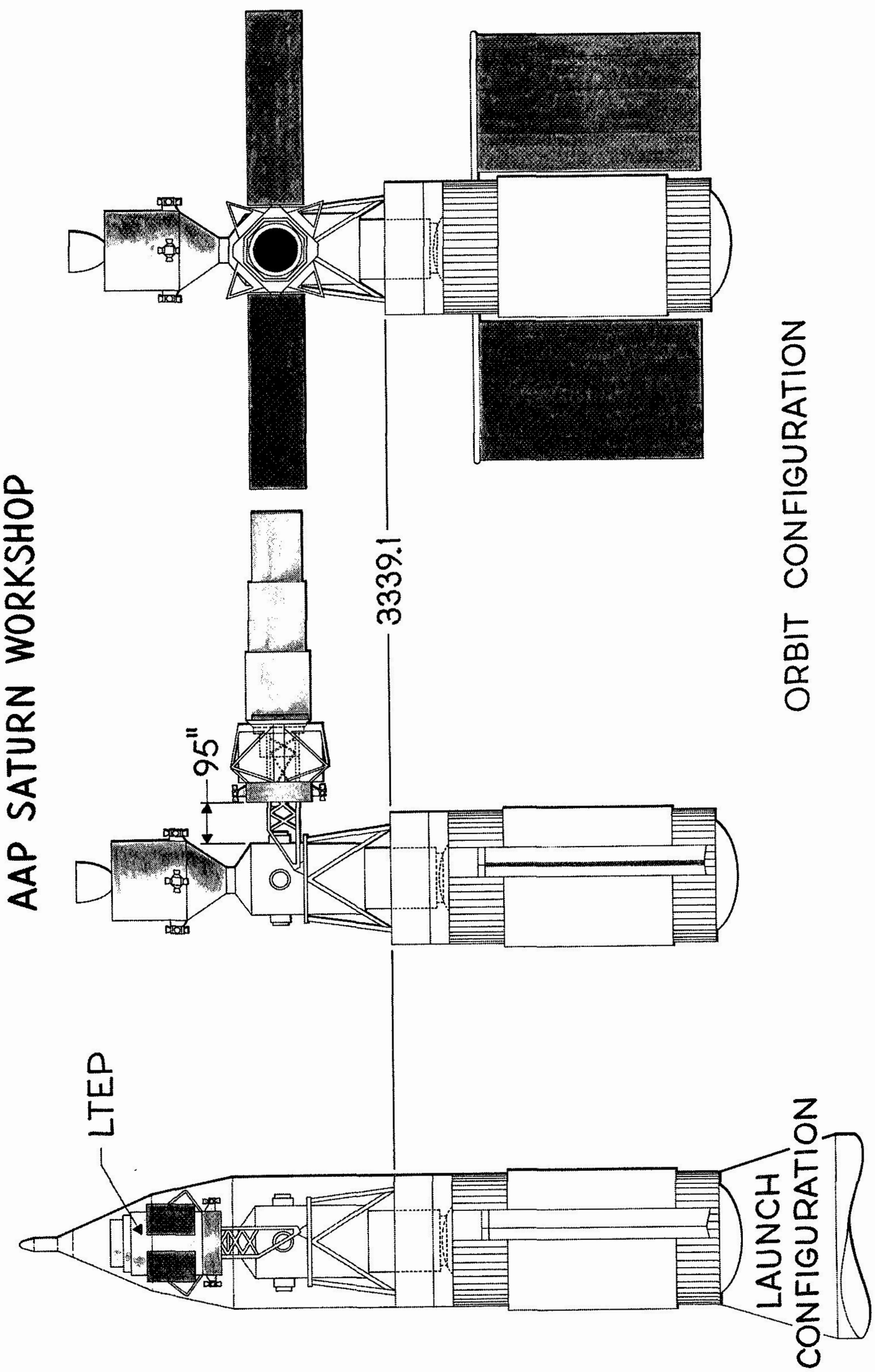


Fig. 4 The SWS-II LTEP (Mode 1)

The Thruster Attitude Control System (TACS) of the Cluster, located at the aft end of the workshop (SIVB), will orient the total mass in coarse-pointing mode to a star field. The CMG's and Experiment Pointing Control system (in the ATM Rack) will inertially maintain the selected position in space and provide fine-pointing (via the ATM gimbals) of the gimballed telescope. Commands will be sent to and data received from the LTEP Module via hardline connection into the MDA. During the continuous stellar-viewing periods, astronaut activity in the Cluster must be at a minimum to prevent disturbances reaching the telescope and causing beyond-limit oscillations.

At some point in the total mission of the AAP Cluster, probably at completion of the Cluster operating period (approximately 270 days) the LTEP Module will be released from the Cluster and assume an independent or detached flight mode. The following potential operational modes (or combination thereof), must be accommodated by the LTEP system:

- Station-Keeping with Manned Cluster. The LTEP Module will be released during Cluster crew activity period. Operation will be monitored by the Cluster. Commands will be provided by Cluster or Ground Control.

- Free-Flight. The LTEP Module will be released at the end of the manned occupancy period of Cluster operation. It will then operate independently with ground-command link only.

At the point of LTEP Module release from the Cluster, the Cluster will lose its inertial platform capability (CMG's are mounted on the modified ATM Rack, which are part of the LTEP Module). The Cluster, however, can maintain its orbital position and maneuver using its Thruster Attitude Control System. The need for partially-redundant flight control electronics within the Cluster must be investigated if the LTEP Module is released prior to completion of the Cluster overall mission.

1.3.2 The Titan IIIC LTEP (Mode 2 – Independent/Unmanned)

This alternate mode provides for launch on a Titan IIIC of an LTEP Module which, when released in orbit, will operate independently. The launch configuration of the LTEP Module atop the Titan IIIC launch vehicle is shown in Fig. 5. The elements are described following:

a. Adapter. A short truss-frame adapter will be provided. It will be bolted at eight places to the 120-inch diameter support ring strong-points on the Transtage forward cylinder (the Transtage is the upper stage of the Titan IIIC launch vehicle). The upper ring of the truss-frame will mate with the LTEP Propulsion/Support Module. Four sets of springs and pins mounted at 90 deg will provide rigid attachment of the Transtage and LTEP Module during launch and ascent and will provide separation forces upon release. Pyrotechnically actuated pin pullers will be used to release the four attachments following payload fairing jettison.

b. LTEP Module. The LTEP Module, except for the Transtage adapter mountings will be identical to the baseline module described in paragraph 1.3.1. It will comprise the Telescope Assembly, the modified ATM Rack, two ATM solar arrays, and the Propulsion/Support Module.

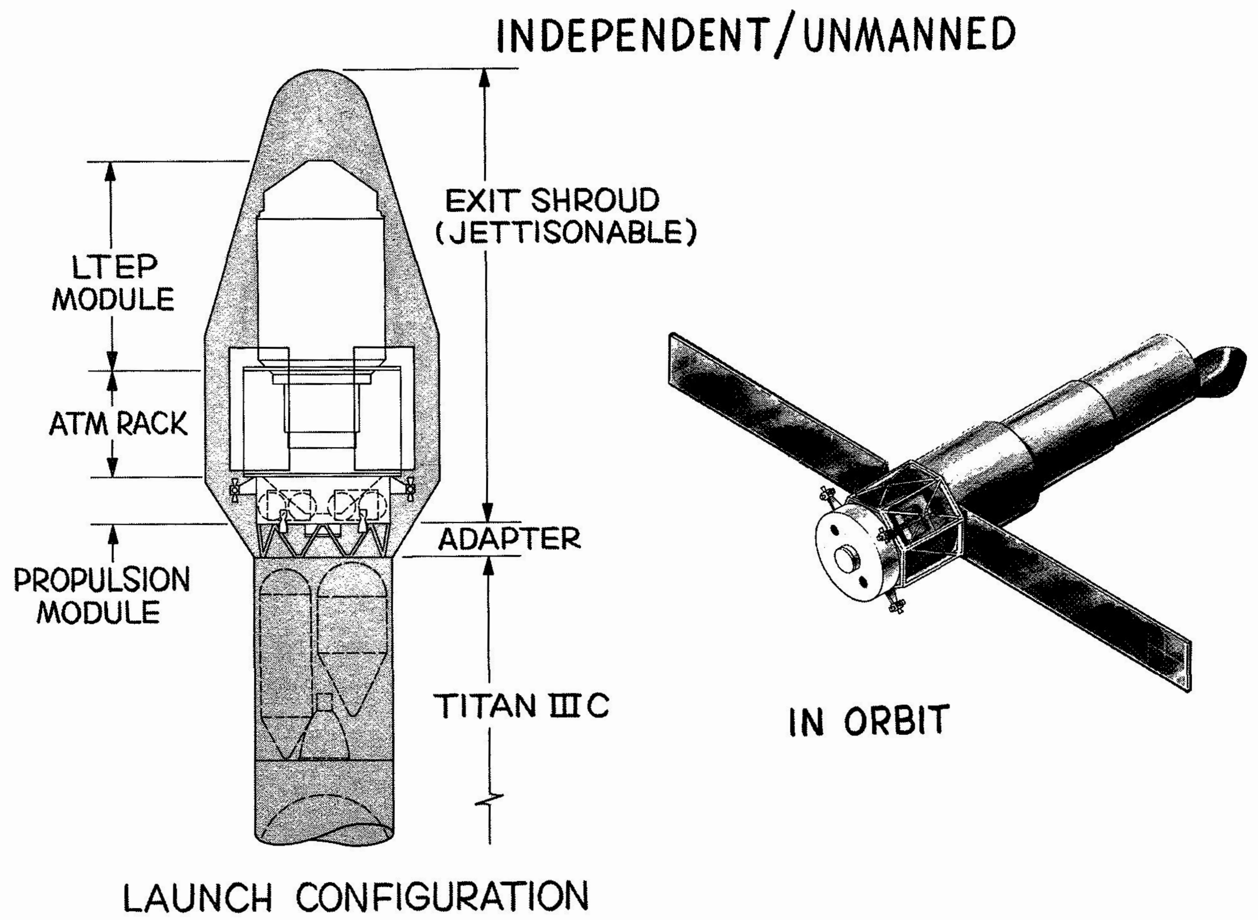


Fig. 5 The Titan IIIC LTEP (Mode 2)

c. Payload Fairing. The payload fairing is a typical hammerhead. To provide clearance for the stowed-position solar arrays, a cylindrical section diameter of approximately 210 inches is required. The ratio of the diameter to the length of the cylindrical section is a parameter which historically has had a minimum slightly smaller than proposed. For reasons of weight conservation, however, the shortest fairing compatible with internal clearances was tentatively established. If proved to be unacceptable aerodynamically, the cylindrical section can be lengthened without affecting the LTEP system (except for some increased launch weight).

The forward cone portion of the fairing is the standard preferred. The 35 deg reverse cone taper to the Titan 120-inch diameter is within Titan payload envelope specifications.

The total fairing is to be constructed in three equal longitudinal sections. A linear charge is placed along each of these mating section lines and around the base (120-inch diameter). When proper altitude has been reached during ascent (when air loads are considerably reduced), the linear charge is ignited and the fairing will split into the three separate elements as it is jettisoned. Small gas jets at the forward end of each element will force that piece radially outward, rotating about a restraining hinge at the aft end (Titan interface).

The launch, ascent, and orbit erection sequence will be essentially the same as for the baseline SWS-II LTEP (Saturn V) launch. The Titan IIIC upper stage, the Transtage, will separate from the basic booster vehicle and transport the LTEP Module into initial orbit position. The payload shroud will be jettisoned after attainment of a specified altitude. Upon reaching orbit position, the LTEP Module will release from the Transtage and execute sequenced operations automatically or, by ground-control command, deploy antennas, deploy solar arrays, spin-up CMG's, extend telescope, activate pointing control system, complete coarse-pointing with attitude control thrusters and uncage the telescope gimbal. The weight of the truss-frame adapter required between the LTEP Module and the Transtage has been estimated at 200 lb. The weight of the payload fairing has been estimated at 2000 lb.

1.3.3 The Rendezvous LTEP (Mode 3 – Independent Launch/Cluster Capability)

This alternate mode provides for launch on a Titan IIIC of an LTEP Module which will, after attaining orbit, rendezvous with an AAP orbiting Cluster and dock for experiment operations (Fig. 6). The launch configuration is identical to that described in paragraph 1.3.2 (the Titan IIIC LTEP). Upon attaining orbit altitude and separating from the Transtage upper stage booster, the LTEP Module will be commanded to maneuver and move slowly toward physical rendezvous with the orbiting AAP Cluster. The Module will be under simultaneous surveillance and command direction by RF from the ground station and from the Cluster.

When the Module reaches a predetermined distance from the Cluster, complete command will be relinquished to an astronaut(s) in the Cluster MDA. A docking maneuver will be completed and the Module docked into a radial docking port on the MDA (opposite the normal deployed position of the ATM Rack). If the LTEP Module CMG's are used for platform stabilization during free flight and during the rendezvous/docking maneuvers, they must be switched off subsequent to docking to the Cluster. It is presumed that Cluster CMG's will be operating prior to the docking.

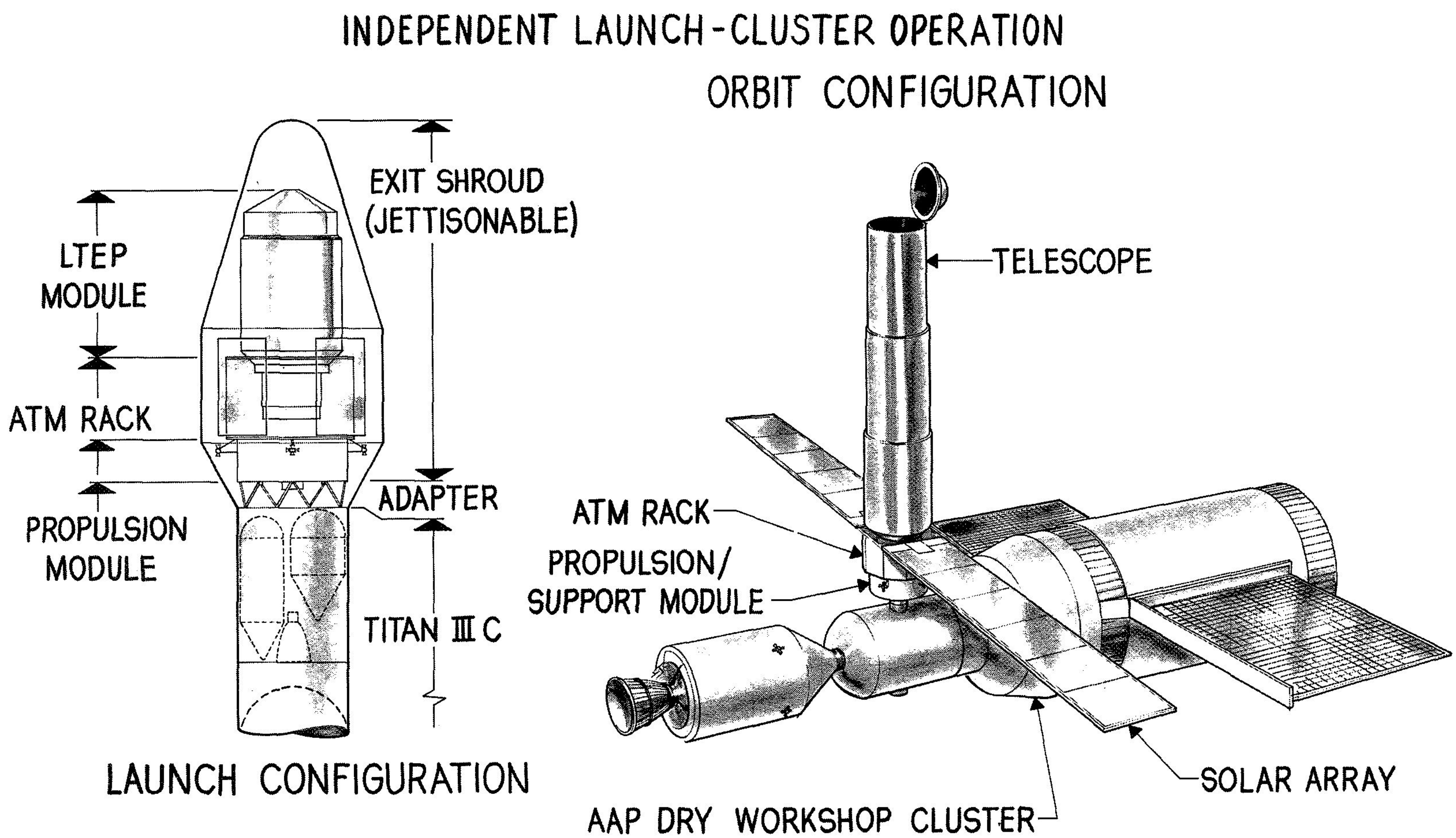


Fig. 6 The Rendezvous LTEP (Mode 3)

The rendezvous radar antenna and transponder required for the docking maneuver are planned as standard components within the Guidance/Navigation/Control subsystem of the Module. (They will also be used for rendezvous and docking with the CSM or the Space Shuttle.) Except for the Apollo probe mounted in the Propulsion/Support Module docking tunnel, the Rendezvous LTEP, Mode 3 configuration is identical to the Titan IIIC LTEP, Mode 2 concept. The docking probe assembly will add approximately 35 lb to the total LTEP Module, making its launch weight 21,600 lb. The Titan launch adapter and the payload fairing also are identical to the Titan IIIC LTEP (Mode 2) weighing 200 lb and 2000 lb, respectively.

1.3.4 The Saturn IB LTEP (Mode 4 – Independent/Manned)

This alternate mode provides for launch on a Saturn IB of an LTEP Module coupled with a man-cell, the Manned Orbital Telescope Experiment Laboratory (MOTEL). After docking in orbit with an Apollo CSM, the MOTEL will provide short duration housing for an astronaut performing simplified monitoring and control experiments with the telescope.

Figure 7 is an illustration of the Saturn IB launch configuration for the independent LTEP/MOTEL Module. The MOTEL is installed between the ATM Rack and the PSM. The total module will be supported by four web-outriggers on the MOTEL to four points on the forward ring of the cone adapter. The module will be separated from the SIVB upper stage at these four points following payload fairing jettison. The elements are described following:

a. Adapter. The adapter is a fixed conical structure 62 inches long attached to the SIVB at the aft end ring (260-inch diameter). Structural reinforcing at four points (at 90 deg) on the forward ring will distribute the point loads into the cone shell. Separation fittings will be provided at these four points to accept pins of the four webs on the MOTEL. Pyrotechnic devices (pin pullers) will release the module upon remote command.

b. Payload Fairing. The payload fairing is identical to that planned for use with the AAP Dry Workshop Cluster payload (on a Saturn V launch).

c. LTEP/MOTEL Module. The LTEP Module elements are identical to the baseline (the SWS-II LTEP) except for minor structural adaptations to accept installation of the MOTEL.

The MOTEL is a simple structural shell, capable of pressurization to approximately 5 psi, and with minimum crew provisions to aid an astronaut in performing simple experiments in conjunction with the LTEP telescope. Although control and display equipment can be elaborated to any level of sophistication desired, the conceptual design currently envisions (1) a small display panel, containing display of major telescope experiment parametric readouts (perhaps including TV image of telescope field-of-view), and (2) a simple control panel which will allow the astronaut to select basic operating modes, to select experiment readout channels, and possibly simple controls for placing biases in the fine-pointing control loop for gross stellar field selection. Handholds and tethers will be provided to facilitate astronaut movement. A set of cabin lights for internal illumination will be installed. Seats or bunks are not planned

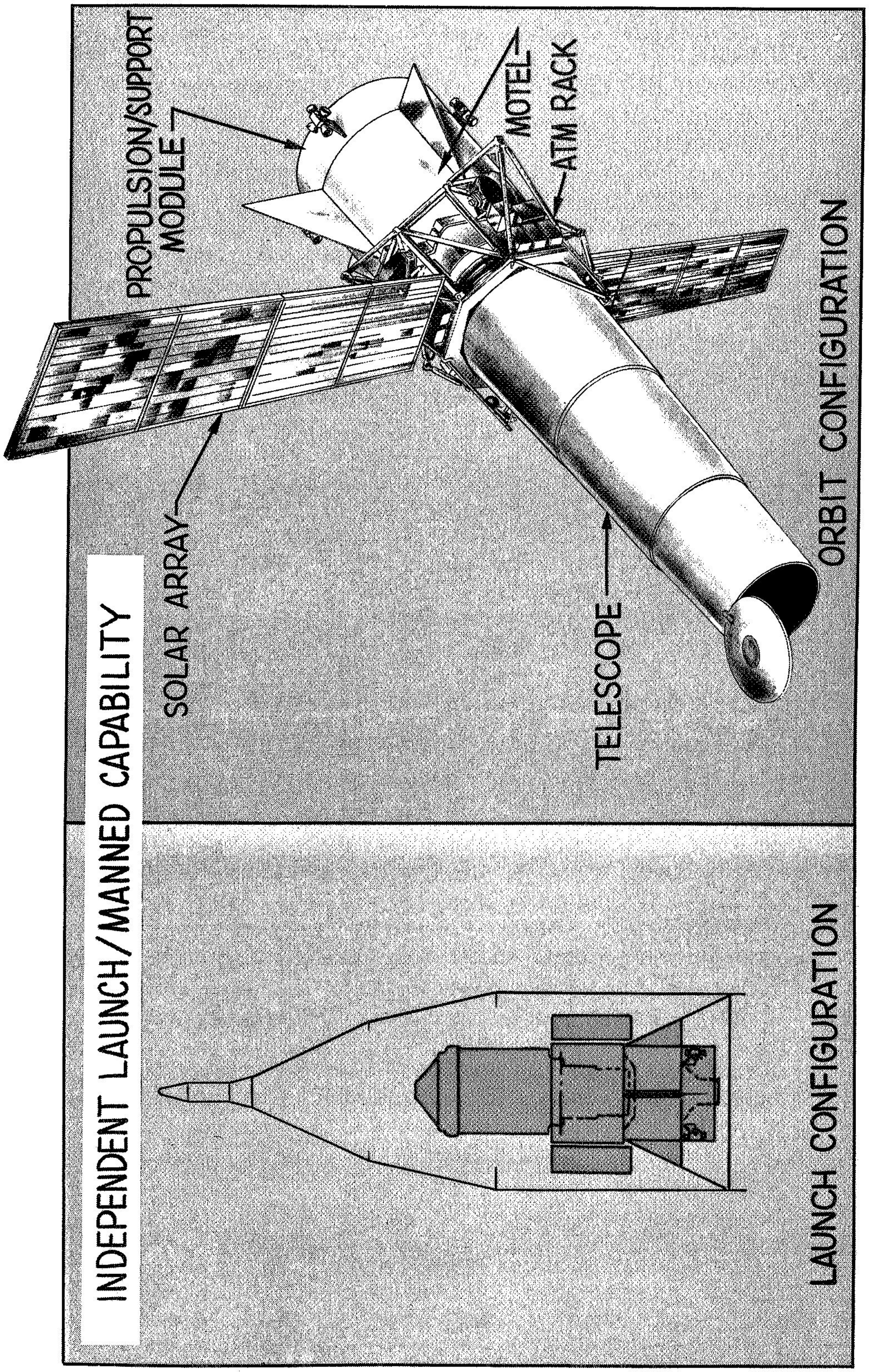


Fig. 7 The Saturn IB LTEP (Mode 4)

because of the short duration (3 or 4 hours) occupancy. Open-hatch operation with the docked CSM is planned with compartments pressurized and a blower-duct from the CSM supplying replenishment life support gases and temperature control for the MOTEL. Temporary hardline electrical connections will be stowed in the docking tunnel and manual connections made by the astronaut after the pressure hatches are opened.

The full cavity of the MOTEL and the inner conical shell of the PSM form a gas-tight enclosure. After the CSM is docked, the PSM will be pressurized by gases from the CSM (via a valve in the docking tunnel hatch). When pressures in both volumes have equalized, the tunnel hatch and the probe/drogue assembly will be removed. Blower and return ducts will be taken from stowage position in the CSM and clipped in place onto brackets provided in the PSM. Electrical connection between PSM and CSM will be made by the astronaut in the docking tunnel, completing the hookup of the CSM with the MOTEL. A hatch with a porthole will be provided in the end of the MOTEL facing the telescope. This hatch may be opened for access to the bottom of the telescope equipment bay (after pressure is reduced in both the CSM and MOTEL). The operational sequences for launch, ascent, and telescope deployment in orbit are the same for The Saturn IB LTEP (Mode 4) as for The SWS-II LTEP (Mode 1). The special operations involving CSM docking and MOTEL occupancy by an astronaut have been considered. In consideration of astronaut safety, all interconnects between the LTEP/MOTEL and the CSM will be quickly detachable or automatic-decoupling. It is planned that the electrical connector be a breakaway type where a quick pull on a lanyard release will separate the spring-loaded halves. Also, the clips for the ventilation ducts attachment in the PSM must be detachable with a light load (perhaps magnet-mounted to small metal plate on the structure). Emergency equipment will be stowed in the MOTEL.

1.3.5 Additional Considerations

In addition to studies of the primary Modes 1 through 4 configurations and their application independently and with the AAP Orbiting Cluster, a Space Station and/or Space Shuttle application and installation of a 3-meter telescope in the Space Shuttle appear feasible. The elaboration of the MOTEL into a HOTEL (Habitable Orbital Telescope Experiment Laboratory) for extended-duration manned independent operation has been studied.

The LTEP Module (comprising Propulsion/Support Module, ATM Rack, Solar Arrays, and Telescope Assembly) can operate attached to, or in station-keeping with, the proposed Space Shuttle or Space Station. The Space Shuttle has adequate volume in its cargo bay to stow the LTEP Module. Presuming that cargo bay doors can be opened in space for the 40 ft long segment of the cargo bay, the LTEP Module would be supported rigidly during ascent on a truss-frame within the cargo bay and when in orbit would be rotated to "aiming" position using the Shuttle as an inertial platform, moved out of the cargo bay in linkages and deployed for free-flight, or moved out of the cargo bay by linkages and attached to a Space Station docking port. Using the Shuttle as an inertial platform would probably negate the use of the CMG's as a stabilizing device for the Shuttle/LTEP combination because of the very large mass and inertias of the Shuttle. Further analysis is required of this mode at such time as the Shuttle orbit flight characteristics are established.

The LTEP Module could be delivered to a Space Station by a Space Shuttle vehicle. The LTEP Module can be mechanically attached to a Space Station port by the Shuttle or after release from the Shuttle can be "flown in" for docking to the Space Station by combination of rendezvous electronics aboard the LTEP Module and RF commands from the crew control panel in the Space Station near the docking port. Here again, the LTEP CMG's will probably be ineffective in inertially holding the space station in a stellar-pointing position. It has been tentatively assumed that the space station control system will provide coarse-pointing and stabilization within limits compatible with the LTEP system fine-pointing capability. The existing ATM gimballing system could be used if this were the case (the CMG's would be omitted if later free-flight were not planned). If the total Station/LTEP combination were inertially fixed and stellar-pointing, movable solar arrays would be required on the Station to sustain electrical loads for the long pointing periods (several hours to 4 days). This case will require further analysis when the electrical power system for the Space Station is more firmly defined.

A 3-meter telescope can be mounted in the cargo bay of the proposed space shuttle. Because of the very long extended length of the telescope, the tube is conceived as a three-section retractable arrangement (similar to the proposed LTEP 2-meter concept). This allows the secondary optics support to be a one-piece pre-installed element calibrated to the primary mirror. The shuttle could transport the telescope to orbit and deploy and release it to a free-flight condition. An alternate mode would have the shuttle performing as the space platform for the telescope. The telescope would be deployed from the cargo bay on a rigid linkage mounted to the shuttle and be erected. In the latter mode, the telescope could be man-controlled; a pressurized and instrumented compartment in the shuttle passenger volume could be utilized. For either the free-flight or the shuttle-attached mode, the rotatable solar arrays could be extended to supply power for long-term (multi-orbit) operations. Adding an integral man-cell to the 3-meter telescope would require lengthening of the retracted length approximately 100 inches to allow for the added module. There is adequate cargo volume available for this enlargement of the payload.

In lieu of the MOTEL, which is dependent on the CSM for a pressurized volume, in which an astronaut can perform some simple experiments or maintenance operations in a short period of time (2 to 4 hours), a HOTEL module has been conceptually designed which offers long-term astronaut support with complete environmental control and life support subsystems. The basic structural shell is the same; however, crew equipment and expendables are added to allow an astronaut to remain in the completely independent LTEP/HOTEL Module for up to 30 days. Free-flight manned experiments can be performed after undocking of the man-delivery vehicle (a CSM or a Space Shuttle). Re-docking would be accomplished at the end of the manned experiment period; the LTEP/HOTEL Module could then be placed on "automatic" and continue orbit operations. The astronaut would have voice communication with the orbiting "team" vehicle and with earth via the Communications & Instrumentation subsystem in the LTEP Propulsion/Support Module. He also would be provided with override command on the primary flight controls of the LTEP Module. The external dimensions of the HOTEL are proposed to be identical to the MOTEL so that a step development approach can be used if desired. The weight of the HOTEL, provisioned with expendables for a 30-day independent mission, is estimated at 2715 lb.

1.4 SPACECRAFT SUPPORT SYSTEMS

1.4.1 Saturn Payload Enclosure

The payload fairing encloses the truss-frame support and the ATM payload. The critical clearance between the fairing and the payload occurs with the fixed sun shade (mounted atop the ATM Rack). The LTEP Module mounted on the Dry Workshop swing links is a nominal 5-inch clearance between the adjacent docking ports of the MDA and the LTEP Propulsion/Support Module (PSM). The Dry Workshop payload fairing will enclose this payload arrangement but with a fairly close fit between the forward cone of the fairing and the LTEP telescope caging structure. If this arrangement is implemented, snubber blocks of resilient material should be placed between the fairing and the caging structure (compressed slightly) to prevent "bumping" during launch and ascent vibration and deflection conditions. A similar close-fit exists between the folded solar arrays and the fairing. Detail clearance layouts of these areas are required as the Saturn Dry Workshop fairing design is firmed up and when the LTEP specific configuration has been selected.

To provide sufficient clearance for the complete LTEP Module with the 3-section telescope, the 762-inch long payload fairing must be moved away from the SIVB interface at Station 3339.095 approximately 55 inches. A simple cylindrical adapter can be added. This is the preferred launch configuration for the LTEP system, allowing both a versatile LTEP Module and providing a simple payload fairing interface with other Dry Workshop launches. It is understood that NASA/MSFC currently plans an adapter forward of the Instrumentation Unit (IU) section of the SIVB. If this adapter, when Dry Workshop dimensions are firm, is 55 or more inches in length, a duplicate can be added for the aforementioned LTEP payload fairing requirement. This approach constitutes the recommended concept for implementation of the baseline LTEP system (The SWS-II LTEP).

1.4.2 Overall Launch Concept

Presently, the pivot pin for the launch lock is mounted to the telescope girth ring. Adjustable snubbers bear against friction pads on the gimbal and roll rings, (to damp launch vibrations) and retraction of the links is caused by two heavy clock springs after the pins are pulled.

With the objectives of simplification and rigidization, the 3-section telescope concept was developed for LTEP. A primary advantage of this concept is the rigid, one-piece quartz rods (set of 4) which support the secondary mirror frame. The caging frames for the inner gimbal ring will provide rigid support of the telescope tube during launch and ascent. Because there is no external caging frame proposed for this configuration, all side-load components will be sustained by the caging frames in the ATM Rack, either in lateral shear or in differential fore-aft loading (moments about the center of mass of the telescope assembly). The telescope will be statically balanced fore-aft about the gimbal plane but the inertial masses may create some relative moments during pitch or yaw maneuvers of the launch vehicles. A detail load analysis in this area should be accomplished during the Phase B follow-on study to verify structural compatibility with the ATM Rack components.

In the 3-section stowed arrangement, the lower fixed section of the telescope will perform as a "box" in which is loaded the two extendable sections. The "lid" of the box will comprise a stowage cover and the sun shield. The cover is attached permanently to the end ring of the smallest telescope section. The shield is hinged on one side and secured with a latch located opposite (at 180 deg). A lower retainer ring is provided on the base of the fixed section to restrain the retracted telescope sections from lateral movement and to sustain aft loading during launch and ascent. The stowage cover rests against the top ring of the intermediate telescope section, and is attached to the fixed section at two points (180 deg opposed) with pin puller devices (pyrotechnic actuation). The figure sensor support frame will be keyed to the secondary mirror frame (one cone-point pin in each of the four webs) to prevent lateral movement of the secondary mirror (the figure sensor frame webs will react lateral loads directly into the smallest-diameter telescope section). Upon attainment of orbit position, the stowage cover latches will be released, the telescope sections extended and the sun shield latch released. Following coarse-pointing stabilization, the ATM gimbal caging frames will be disengaged.

The LTEP Module will be completely checked out in the Vehicle Assembly Building prior to movement to the launch pad. All subsystems of the LTEP Module will be dormant during the pre-launch countdown except for monitoring a few temperature and pressure transducers. These data will be transmitted via hardline into the cluster and combined with other data going to ground control via the main Cluster launch umbilical. Air conditioning (via ducting) will probably be supplied to the interior of the payload fairing for temperature control of Cluster elements. This forced-ventilation cooling will be adequate for the LTEP Module. Ground communications will be provided by the launch vehicle (SIC/SII) and the Dry Workshop (SIVB) during launch and ascent; all commands to the LTEP Module will be via S-band to the Cluster Communications and Instrumentation (C&I) thence hardline via the MDA to the LTEP Module.

The movement limits and pointing/stability accuracies are as follows:

- <u>Telescope Mechanical Limits</u>

Movement about X and Y Axes	±2 deg
Caging Position (X and Y)	±10 arc sec
Movement around Z Axis (Roll)	±95 deg
Roll Error (from Selected Position)	±10 arc min

- <u>Attitude Control Thruster Maneuver</u>

Coarse Pointing Tolerance - Cluster-Attached Mode	±0.3 deg
Angular Rate (Maximum) - Any Axis	0.3 deg/sec
Coarse Pointing Tolerance - LTEP Independent	±1.0 deg
Angular Rate (Maximum) - Any Axis	1.0 deg

- ATM CMG Control Limits (Without TFPC) - 2σ values

About X Axis	±215 arc sec
About Y Axis	±345 arc sec
About Z Axis (Roll)	±300 arc sec

- Telescope Fine Pointing Control (TFPC)

About X Axis	±2.5 arc sec
About Y Axis	±2.5 arc sec
About Z Axis	CMG control

Equipment peculiar to the LTEP system is described in the following paragraphs.

1.4.3 Program-Peculiar Elements

Special elements required for the LTEP system operation with the AAP Cluster, exclusive of the subsystems described in paragraph 1.4.4 are the telescope erection mechanism, the Propulsion/Support Module (PSM), the modified ATM Rack, and the rotating devices for the ATM solar arrays and for the Workshop solar arrays. The conceptual design of the LTEP program-peculiar elements is presented following.

1.4.3.1 Erection Mechanisms and Extend-Locks. The screw-jack extension mechanism embodies drive motors with appropriate gearing which are provided for each screw-jack. The motors are slip-clutched so that if a motor fails, the gear train can be driven by the other motors via the interconnecting flex shafts. A manual crank can be installed on at least two of the four motor gear boxes to afford handcranking by an astronaut as a backup mode for telescope extension. Screw-jacks will be of the ball-screw or tapered-roller/acme screw types to provide minimum friction and zero-slip fit. The screw-jacks in the retracted position can be used to restrain the stowage cover in the down (and locked) position. The use of the screw-jacks to hold the telescope in the extended position may also be feasible. Irreversible screws combined with overdrive-position compression springs on the end of each screw would allow the sections to be extended against "stop" blocks (for precision extended position) and held in tension by the override compression springs. The screw-jacks can be made reasonably strong for cantilever bending loads without significant weight increase, and in the extended and pre-loaded condition, possibly can sustain the small loads on the telescope sections resulting from angular accelerations. This potentially would allow reduction of the tube skin thicknesses and weight.

An alternate extension system was developed initially for a 6-section telescope but the concept can be applied to the 3-section configuration. This design comprises a motor and cable-winch which winds up a cable; shortening of the cable "pulls" each section out of its stowed position until all sections are extended and wedge-locked in that position. Multiple cable systems, at least three equally spaced around the circumference, are envisioned with redundant motor drives on each system.

1.4.3.2 LTEP Propulsion/Support Module (PSM). Because one of the flight modes of the AAP Workshop involves free-flight of the LTEP Module (separated from the Cluster), a full complement of support subsystems, including propulsion/attitude control, must be provided. Limited additional packaging space within the ATM Rack envelope and the objective of maintaining the minimum-diameter envelope were used as the basis for conceptual development of a versatile but essentially simple Propulsion/Support Module (PSM). The PSM will attach to the end octagonal bulkhead of the ATM Rack.

The basic configuration of the PSM is shown in Fig. 8. It is a 120-inch diameter cylinder 40 inches long with a 15-inch long docking tunnel/ring and outrigger struts at four places each supporting a cluster of attitude control thrusters. The features of the module are:

Basic Structure. The structure comprises an outer cylindrical shell, an inner conical shell, four radial webs, and a docking tunnel assembly. Extensions of the webs externally support the thruster clusters. The structure is conventional riveted or welded aluminum alloy. Quick-open access doors will be provided in the cylindrical shell to allow direct access to the equipment compartments by astronauts performing in-orbit inspection and maintenance.

Docking Provisions. An Apollo docking ring and drogue cone will be mounted in the structural tunnel. This is a provision which has been added to allow docking of the manned Apollo CSM. An astronaut can gain access through this tunnel to the bottom end of the telescope without utilizing EVA; this may afford reasonably simple removal of data packages from the telescope experiment/equipment compartments.

Equipment Compartments. Two equipment compartments will be provided to house all subsystem components requiring relatively uniform or small excursion temperature control. Flight control, communications and instrumentation, and electrical components will comprise the installations. Packaging will allow easy removal and replacement of modules, primarily those whose failure or malfunction probability is lower than others.

Propulsion and Thrusters. The propellant and pressurant tanks will be installed peripherally within the cylindrical shell as shown. Two axial thrusters will be mounted on radial webs and nozzles will extend through the bottom plate. Four thruster clusters will be installed on the outrigger beams.

Micrometeoroid and Thermal Protection. The external surface of the PSM will be covered with a sheet metal micrometeoroid shield placed approximately one inch out-board of the structural shell and supported by insulation standoffs. The cavity between the shield and structural shell will be fitted with insulating foam or multilayer insulation.

Special thermal coatings on the external surfaces, the internal surfaces, the equipment compartments, and the tanks will provide a semi-passive thermal control arrangement, utilizing electrical heaters only to provide the necessary heat balances.

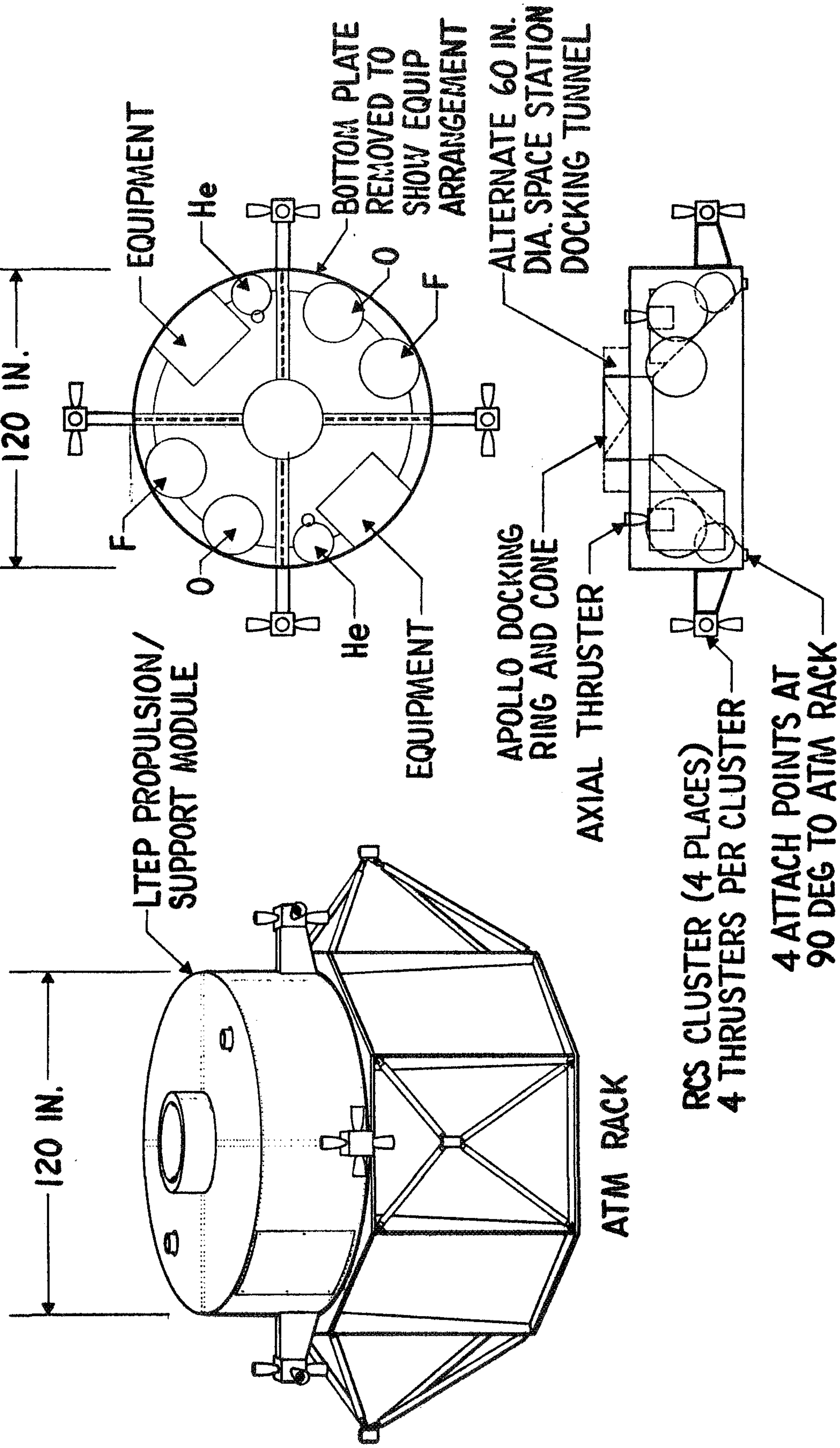


Fig. 8 LTEP Propulsion/Support Module (PSM)

1.4.3.3 Modified ATM Rack. The ATM Rack, designed to support the Solar Telescope, is essentially adequate to use with the LTEP system; however, certain modifications are required to (1) remove structure and components not needed for the LTEP application thereby reducing the weight, and (2) adding single-axis rotation mechanisms for two ATM solar arrays (presently fixed).

The basic structure of the ATM Rack includes four outrigger strut assemblies, previously used to support the Rack on the Saturn Launch Adapter (SLA), are not required for the LTEP installation. Also, the solar shield and its support structure are not used with the LTEP system which is not sun-oriented. To reduce the overall length and weight of the structure, it is proposed also that the structural segment which is identified by the 16.4 dimension be removed and the solar array hinge line relocated approximately 12.4 inches to Station 1732. Finally, the mounting provisions for the LM Ascent stage should be removed and provisions added for 4-point attachment of the Propulsion/Support Module to the Rack bulkhead at approximately Station 1833.5. Except for protrusion of CMG's and equipment packages, the ATM Rack will, when modified, have an overall structural envelope of an octagonal prism, 133 inches across flats and 97.5 inches long.

Because of reduced electrical power requirements for the LTEP system, the 972 lb of equipment will be deleted including measuring distributor, nine charger/battery/regulator modules, two switch selectors and two control distributors. In addition, the net equipment mounted on the end bulkhead will be relocated outboard to clear the 120-inch diameter Propulsion/Support Module or will be relocated to open areas on the vertical side panels (areas made available by equipment deletions).

1.4.3.4 Modified ATM and Workshop Solar Array Installations. The current Dry Workshop Cluster configuration contains four ATM solar array wings fix-mounted to the ATM Rack and two Orbital Workshop (OWS) solar arrays fix-mounted to the SIVB structure. All arrays are folded for launch and extended after orbit-position is attained. Because of the complete spherical pointing requirement for the LTEP stellar-field pointing, single-axis rotatable solar arrays are required. The 360 deg rotation device for the ATM arrays will be a new-development item for the LTEP system. The ±180 deg rotation device for the OWS arrays was planned as a modification of previous Saturn hardware.

1.4.4 Spacecraft Subsystems

Extensive consideration was given to the spacecraft subsystem concepts. Some principal conclusions resulting from these analyses are given in the following paragraphs.

1.4.4.1 Structure and Orbital Propulsion. The AAP Dry Workshop Cluster approach offers a significant improvement to adaptation of the LTEP system to the orbiting-Cluster program. The elimination of the LM Ascent Stage allows application of a simplified and versatile LTEP Propulsion/Support Module (PSM) both on the Cluster-attached and Independent missions. The basic ATM Rack appears usable for the LTEP system mounting with only minor structural modifications and equipment relocations (relocation of equipment boxes on the top bulkhead to vertical side panels of the rack).

There appear to be definite advantages in a change from a 6-section to a 3-section telescope (this is the change allowed by increased payload packaging volume on the Dry Workshop Cluster piggy-back launch): lighter weight (fewer rings), simpler extension mechanism, greater rigidity, reduced structural misalignment, and improved mounting of secondary mirror (on non-folding support rods). The mounting of the launch-stowed telescope with the tube extension pointing "up" provides improved launch/ascent load sustaining by the launch caging mechanisms (major axial loads tend to retract rather than extend the telescope, placing much smaller loading on the caging structure/devices).

The mass properties of the total LTEP Module are estimated as follows:

WEIGHTS OF CLUSTER AND LTEP ELEMENTS (lb)

	Cluster ATM	Cluster/LTEP	Independent LTEP
Cluster (less ATM Rack, Solar Telescope/Spar, and Solar Arrays)	99,160	99,160	-
ATM Rack	9,235	-	-
ATM Rack (Modified for LTEP)	-	8,150	8,150
Solar Telescope and Spar*	5,535	-	-
LTEP Telescope*	-	8,096	8,096
Propulsion/Support Module	-	3,965	3,965
ATM Solar Arrays	4,070	2,035	2,035
Cluster/ATM Total	118,000 lb		
Cluster/LTEP Total		121,416 lb	
LTEP Module Total			22,256 lb

*Gimballed masses

MOMENTS OF INERTIA (slug-ft^2) ABOUT C.G. OF ELEMENT

Individual Element	I_X	I_Y	I_Z
LTEP Telescope	23,278	23,278	1,388
ATM Rack (Modified for LTEP)	5,683	5,948	7,668
Propulsion/Support Module	1,189	1,192	1,961
Solar Arrays (2)	27,761	27,761	55,261
LTEP Module Total	66,115	66,378	66,290
Cluster/ATM Total	1,182,000	7,130,000	7,460,000
Solar Telescope and Spar	1,107	2,464	2,479

No major problems are anticipated in the structure and orbital propulsion subsystem areas. The orbital propulsion subsystem is a straightforward adaptation of existing components with the exception of the propellant tanks which have been sized for the LTEP Module (2,600 lb usable propellant). Elements of the tanks (standpipe, bladders, etc.) have been space-qualified).

1.4.4.2 Electrical Power Subsystem. Several basic conclusions were derived from examination of the standby and operating mode power requirements:

a. Neither the Cluster/LTEP nor the Independent LTEP can be operated with fixed solar arrays.

b. The lightest weight solar array concept for the Cluster/LTEP results from the use of single-axis pivot (360 deg rotation) on both ATM and OWS solar arrays combined with Cluster/LTEP rotation about the telescope line-of-sight for sun-line aiming of solar arrays.

c. Use of four solar array wings on the LTEP (ATM), for either Cluster-attached or Independent operation is inefficient. Using two wings and mounting at 90 deg to the longitudinal axis of the Cluster and telescope offers a minimum-weight approach with no shadowing effects; this concept is recommended.

d. Two of the existing ATM solar arrays combined with nine of the ATM batteries can provide required electrical power for LTEP in the Independent mode. In the Cluster-attached mode, where the Cluster subsystems are substituting for LTEP subsystems (attitude control, communications, etc.), the electrical loads are lower, and some of the wattage can be made available to the Cluster via the existing power transfer devices for supplementing the CSM support power (CSM docked with fuel cells dormant).

e. The life expectancy of the proposed solar array/battery system is at least 2 years, limiting the battery discharge depth to a maximum of 30 percent. Extrapolation of operating time beyond that period is difficult because of the small amount of data available on long-term orbit degradation of solar arrays. Actual testing with a simulated environment and analytical review of data and hardware from similar spacecraft programs will be necessary to justify estimates of longer duration operation without replacement.

1.4.4.3 Guidance and Control Considerations. The basic results of the guidance analysis effort are a) that the output frequency of the gimbal control system is approximately 2.5 cps and b) that the output amplitudes are ±1.77 arc sec in the planes including the X and Y axes and ±38 arc sec about the Z (roll) axis of the telescope. Spectral distribution of the major error inputs to the telescope from the gimbal remains to be derived. The net anticipated outputs of the ATM system are as follows:

X Axis	Amplitude	±1.77 arc sec
	Freq.	2.0 to 2.5 cps
Y Axis	Amplitude	±1.77 arc sec
	Freq.	2.0 to 2.5 cps
Z Axis (Roll)	Amplitude	±38 arc sec
	Freq.	0.08 to 0.10 cps
	Rate	0.35 to 7 deg/sec

The attitude control system proposed for the LTEP mission comprises the same componentry as the AAP Cluster/ATM system. Because the ATM solar telescope is aimed toward the sun, two sun sensors and a single star tracker are used for sensing in the acquisition mode. A proposed modification for the LTEP mission utilizes a fixed star sensor and a gimballed star tracker mounted on the ATM Rack. A precision target star sensor is mounted on the gimballed telescope. The telescope gimbal is caged in the null position until the ATM Rack control system brings the target star into the field-of-view of the precision sensor on the telescope tube. The following is a description of the system function.

a. Initially, the telescope will be locked in a neutral position by the caging mechanism until the total vehicle is pointing roughly at the target star (for observation) while maintaining a roll reference using a second reference star (Canopus or other).

b. The inner reference for vehicle attitude is provided by three body-mounted, single degree-of-freedom, rate-integrating gyros.

c. Signals from the gyros are applied through compensation and deadband circuits to the SIVB RCS thruster valves or to the PSM thruster valves. The same gyro signals are processed to generate the necessary CMG control signals.

d. The CMG's provide a vernier moment generation system within the deadband of the reaction control system. When the CMG's are not capable of compensating for a particular disturbance, an overload condition occurs, driving the CMG's to their gimbal limits or to an orientation where the spin axes are parallel.

e. When this condition occurs, the RCS is activated. The RCS is in operation also when any other particular error signal indicates vehicle position is outside the RCS deadband.

f. During periods of star occultation, the absence of the signal from the star sensor releases a relay and the attitude reference reverts to the integrating gyros alone. The gyros will hold the vehicle so that the star, when next contacted, is within the field-of-view of the acquisition star sensor for automatic acquisition.

A specific feature of the control system which must be further investigated is the "automatic" activation of the RCS thrusters if the CMG's reach limit travel or if the gyros indicate out of "deadband." A delay may be necessary in the system to allow time for closing the telescope sun-shield (to protect the inner optical elements) before the RCS thrusters are fired and potentially create a contaminant flux into the telescope cavity.

The components of the ATM control system have been designed and tested to specifications requiring 270 days operation. In fact, the CMG's were tested to a much shorter life time criteria and reportedly are now undergoing modifications to provide the 270-day operating ability. Because these mechanical (rotating) units are subject to wearout, a thorough evaluation must be made considering their use for the two years required life of the LTEP system. Although the electronics of the control system are probably capable of the longer life, further investigation is required here also. The integrating gyros must also be fully assessed for life capability.

LMSC has made a worst-case cursory analysis of the distortions which might occur to the telescope tube as a result of the orbit thermal environment and has estimated the gross movements of the tube-end figure sensor and the secondary mirror relative to the primary mirror. The results of this preliminary analysis and initial distortion estimates, hopefully, will assist in making corollary estimates of optical pointing actuator/servo loop requirements to compensate for these potential optical element motions.

1.4.4.4 Communications and Instrumentation (C&I) Subsystem. With respect to the Communications and Instrumentation Subsystem evaluation, the following conclusions were reached.

a. The currently planned AAP Dry Workshop Cluster has adequate capacity and capability for handling all of the LTEP system communications and data processing functions with the exception of the TV network.

b. It it is planned to transmit high-resolution (up to 5000 lines per frame) reproduction of stellar-field photos by TV to ground stations, a multiplexer quantizer element would be added to the existing circuitry to allow pulse-coding and digital transmission of high bit-rate data. The current cluster system handles the TV (small hand-held camera) on analog.

c. The proposed LTEP Communication and Instrumentation (C&I) subsystem comprises a number of existing components which are space-flight qualified. Some are from the Apollo CM system with the remainder from spacecraft produced by LMSC.

d. A primary potential problem exists in selection of proven hardware. Most of the Apollo program hardware was designed and tested to a 200-hour operating life specification. The aforementioned LMSC program hardware, in most cases, is designed and tested to either a 6-month or a 9-month operating life specification. Many of these hardware elements are probably capable of longer operating periods, but there is presently no validation of this capability by analysis, testing, nor operating experience. With the two-year minimum life required by the LTEP system, and considering the potentially large benefits of using proven hardware (even with shorter operating life), it appears mandatory that a strong effort should be initiated to investigate in detail the long-life expectancy of the available hardware tentatively selected for the LTEP system (or equivalent).

e. The Manned Space Flight Network (MSFN) ground stations to be utilized with the AAP Cluster are adequate also for the Cluster/LTEP and Independent LTEP orbiting systems. Ground contact periods per station will vary from 4 to 8 minutes, quite sufficient for the LTEP system (or Cluster/LTEP) data dumps.

1.4.4.5 Crew Support Equipment. The LTEP Module will be equipped with various accessories to aid the astronaut in inspection, adjustment, and maintenance/replacement activities in EVA from the Cluster/Space Station or from the CSM or Space Shuttle support vehicles. The following items are accessible to the astronaut directly without opening of any compartment doors:

- Solar Arrays and Rotation Mechanism
- ATM Rack Equipment Mounted on Exterior Panels
- Screw-Jack Erection Mechanism
- Exterior Surface Thermal Coating on Telescope
- Attitude Control Thrusters
- CMG's (Partial)

The packages mounted internally and requiring access through openings are:

- Sun Shield and Actuator
- Figure Sensor
- Secondary Mirror
- Primary Mirror
- Propulsion/Support Module

The astronaut(s) will be provided the necessary handholds, foot stirrups, tether attach rings, and tether slide-rails to aid in performing the following functions:

a. Emergency extension of telescope using hand-cranking of extension gear box.

b. Inspection, adjustment, or replacement of figure sensor on secondary mirror package.

c. Inspection, cleaning, or removal/reinstallation of primary mirror segments.

d. Inspection and adjustment of basic structural alignment of telescope optical elements.

e. Replacement of sun shield actuator.

f. Data package retrieval and replenishment.

g. Experiment servicing (filter changes, adjustments, etc.)

1.5 SUPPORTING ANALYSES

The cumulative effect of the results and conclusions derived during the LTEP subsystem study effort and summarized in the preceding paragraphs was to reconfirm program feasibility, further define the recommended concept and isolate study areas for Phase B analysis. Several key LTEP study results that were derived in obtaining the principal conclusions evolved from various support study analyses. For example, launch vehicles were compared and examined and the Saturn V, Titan IIIC and Saturn IB systems selected for appropriate modes of implementation. The 220-nm, 35 deg inclined orbit parameters were defined.

The results of the thermal support analysis can be summarized as follows:

a. The conclusions of the previous analyses were reconfirmed; the 2-meter telescope temperature gradient across the mirror will be held to less than $1^{o}C$ utilizing passive techniques. This result applies to both the Cluster-docked and autonomous (Independent) modes of operation.

b. The on-station thermal environment is as previously defined. The "desirable" operating temperature from a spacecraft consideration viewpoint is essentially the same as the previously indicated mirror required operating temperature, i.e., $-80^{o}C$. Operational temperatures from $-62^{o}C$ to $-93^{o}C$ were obtained dependent on the assumed mode and sun angle with a primary mirror temperature level of $-84^{o}C$ for the minimum environment and $-71^{o}C$ for the maximum.

c. The Optical Solar Reflector (OSR) is a stable thermal control surface material with negligible degradation properties. No life-time problems are anticipated.

d. Continual operation at extremely low temperatures (e.g., $-200^{o}C$) is not considered practical. A minimal temperature of approximately $-96^{o}C$ might be maintained passively in a synchronous altitude orbit and $-89^{o}C$ in low earth orbit.

The following summarizes the impact of an LTEP-ATM application upon astronaut considerations as compared with the current solar ATM operations as indicated from analyses of manned operations:

a. The requirements for astronaut scientific and manual control skills are reduced.

b. There are minimum IVA and control procedures changes.

c. There is an added EVA requirement, but it is a logical next step from the first cluster EVA requirements.

d. The quiescence requirement during telescope operation adds a major crew activity scheduling restriction.

e. There are minimum requirements for new or modified crew systems and training equipment.

Resources review and analyses, and generation of preliminary resource plans, resulted in a baseline schedule (Fig. 9) in support of a 1975 launch. A July 1974 launch might be accommodated but would involve critically spanned effort. Preliminary cost plans indicate program requirements between $91M for the simplest (unmanned) implementation mode (The Titan IIIC LTEP or The Rendezvous LTEP) and $134M for the independent, manned concept (The Saturn IB LTEP). The baseline program with the SWS-II would require $100M including AAP support effort.

A separate study contained in Volume II, Appendix A summarizes the results of a preliminary analysis of the various sources of outgassing and other "contaminant" emissions in the LTEP system. It covers both the AAP Cluster-attached mode and the Independent mode of orbit operation. Primary attention was paid to examination of the types and quantities of emission products and an explanation of their origin. Secondary attention was devoted to preliminary assessment of the effect of these contaminants upon optical surfaces and other critical surfaces such as solar arrays, thermal control surfaces, sensor lenses, and antenna surfaces. It appears there is a potential problem with optical surface contamination, mainly by water vapor. Based upon preliminary analyses, however, and compared with the relative intensity of 12th-magnitude stars, the various contaminants, stacked in the telescope field of view, do not seem particularly troublesome. Additional analysis and/or testing is required to (a) establish quantitative values for emission products, and (b) determine the specific effect on critical surfaces and field-of-view distortions or dilutions. Detailed recommendations for this additional effort are described in Volume II.

1.6 CONCLUSIONS

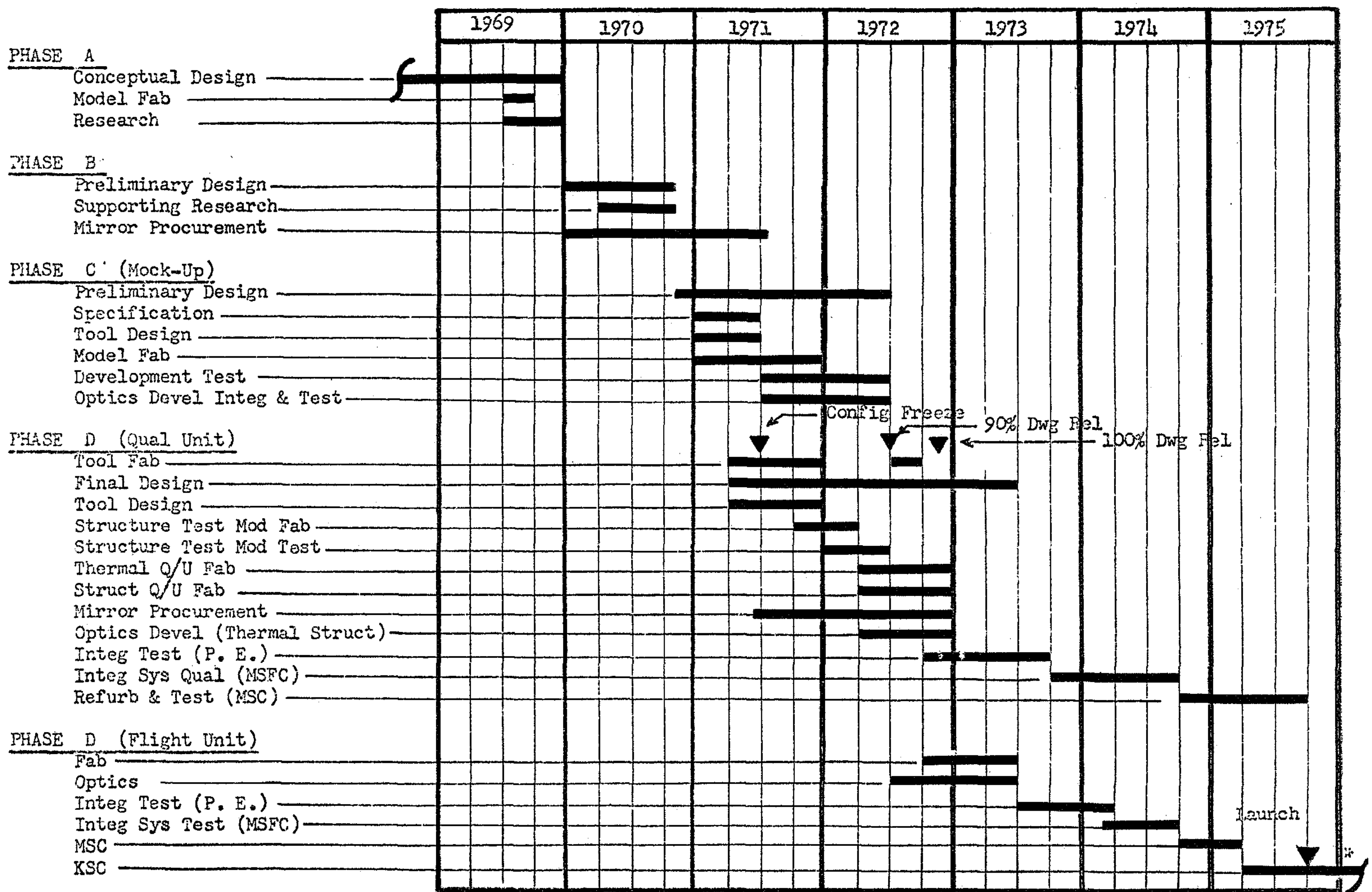
The overall study objectives can be summarized as follows:

- Validate feasibility of implementing the 2-meter system in either a piggyback or an independent (autonomous) configuration.
- Select (recommend) a baseline LTEP implementation approach.
- Define the technology efforts required to initiate the recommended implementation.

The study objectives were met as follows:

Feasibility. The 2-meter system can be implemented, with a minimum of development risks, in either the piggyback or independent (autonomous) modes that were considered. The principal difficulty envisioned in accomplishing the program is a critically spanned schedule if a July 1974 SWS-II launch date is maintained. This criticality is significantly reduced in meeting a mid-1975 or subsequent commitment.

LARGE TELESCOPE EXPERIMENT PROGRAM (LTEP SUMMARY SCHEDULE)



* Indicates 2 year Post Flight & Data Support

Fig. 9 Large Telescope Experiment Program (LTEP Summary Schedule)

Remote (i.e., detached or free-flying) operation requires development of a new equipment unit for mounting of existing propulsion, electrical, and communication subsystem hardware. This containment structure, designated the Propulsion/Support Module (PSM), is not considered a major problem. Implementation of the autonomous concept in a manned operational mode requires development of the Manned Orbital Telescope Experiment Laboratory (MOTEL) system. This life cell support system is a minimum-development, simplified unit providing a shirt-sleeve, visor-up environment for one or two astronauts for periods up to 3 to 4 hours. A more elaborate system designated HOTEL (Habitable Orbital Telescope Experiment Laboratory) is envisioned for use with the space station in the detached operating mode. This more advanced system would permit manned operation of up to 30-day periods.

Implementation Recommendation. As previously indicated, either of the piggyback approaches or the independent concepts are considered feasible. Further, the basic 2-meter telescope configuration will readily adapt to these various operational approaches. Thus, the basic decision as to the optimum program implementation need not be completed prior to continued effort on the system. Phase B effort can proceed on the basic configuration with equal applicability to the ultimate mode of implementation. A programmatic selection will be required at the end of Phase B effort (i.e., late CY 1970). This is particularly true if the earliest flight date (July 1974) is selected for the telescope launch. Early initiation of development of the basic 2-meter telescope configuration with the Propulsion/Support Module is recommended.

Phase B Effort. The five key items to be accomplished in the spacecraft support areas in performing the Phase B (definition) program are refinement of the attitude control and stability analysis, quantitative evaluation of outgassing effects, structural and dynamic analysis of the spacecraft system, evaluation of the life time potential of critical system elements and further definition of the astronaut operations and requirements for manned support. In addition, the generated preliminary resources planning data can be modified and/or supplemented to facilitate program evolution. This refinement, however, can be made more meaningful upon completion of the NASA decision as to the final mode of program implementation.

Thus, the study objectives have been accomplished. The resulting baseline system and alternative modes of operation are described in detail in Volume II - Technical Report.